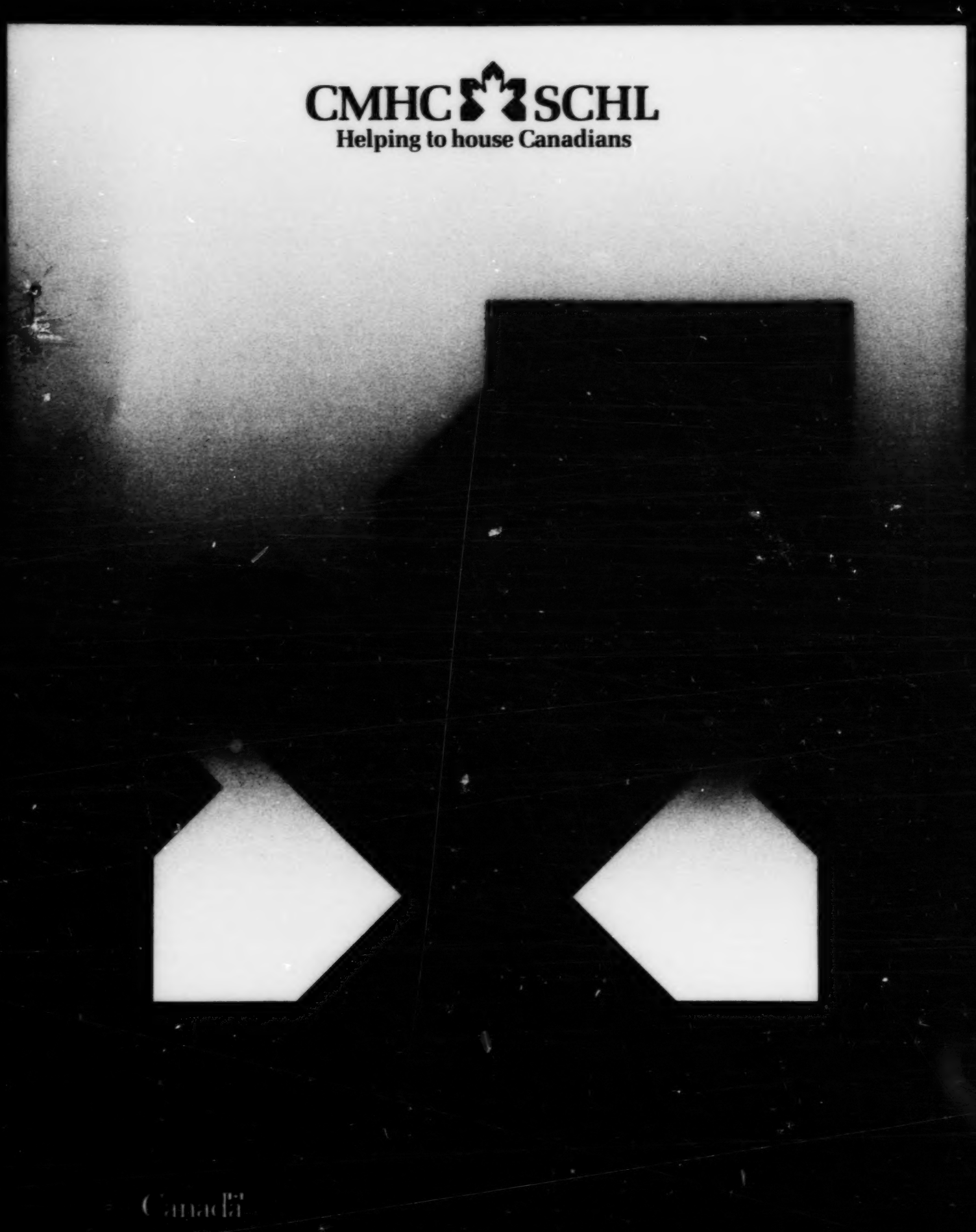
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THE COSTS AND BENEFITS OF SMOKE ALARMS IN CANADIAN HOUSES

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Report for

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COSTS AND BENEFITS OF SMOKE ALARMS IN CANADIAN HOUSES

The study was intended to establish the effectiveness of smoke alarms, evaluate the costs and benefits of extending their use to houses that do not currently have them, and consider ways of improving their dependability in use.

The study investigated and analyzed Canadian and American fire records from 1980 to present. The study concludes that smoke alarms are saving about 26 lives per year per million new houses at very small or nil cost per life saved. The report also concludes that the opportunity to extend smoke alarm protection to the 18% portion of Canadian houses still without smoke alarms and to ensure that the protection is maintained in other houses is one of the greatest life-saving and cost-saving opportunities open to society.

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THE COSTS AND BENEFITS OF SMOKE ALARMS IN CANADIAN HOUSES

INTRODUCTION

The recent study of the potential costs and benefits of installing sprinklers in new houses, sponsored by Canada Mortgage and Housing Corporation (1)(2), concluded that the net cost of saving a life with sprinklers would be $38 million or more. This cost was derived after due allowance for potential savings in property damage, injuries and fire service costs. When compared to the cost of saving lives calculated for a number of other safety laws, sprinklering houses can be seen as an extremely poor use of money.

Fire records examined in the CMHC study led to the conclusion that newer houses were about 3 1/2 times safer than the general housing stock. Not only were newer houses safer than older houses, but the whole housing stock was becoming much safer. Although increased safety was attributed to a variety of reasons, by far the major factor was seen to be the widespread use of single station smoke alarms. Indeed, it may be primarily the remarkable efficacy of these low cost devices that now leaves sprinklers with very little opportunity to save lives, and thus drives their cost of saving a life to such heights.

Single station smoke alarms, introduced in 1970 as self-contained battery operated devices, decreased in cost as their use increased. By 1975, their cost was reduced to the point where they became generally attractive for most households. By 1988, it was estimated that 83% of owner occupied Canadian households and 74% of tenant occupied households were protected with smoke alarms (3). Canadian usage generally paralleled that of the U.S., which by 1987 was estimated to have alarms in 82% of their households (4).

In view of the apparent effectiveness of smoke alarms in increasing life safety, and their relatively low cost, it was seen that it may be very cost effective to encourage their use in households not currently protected. Further, improving their dependability was also seen as an area of considerable benefit. In 1987, for example, in U.S. houses that reported fires, about 32% of the smoke alarms were not operational (4). According to one study, most inoperative alarms resulted from dead or missing batteries, power disconnections, or improper installation (4). It was reasoned, in the CMHC sprinkler study, that certain changes might be made in the design or installation of smoke alarms to increase their dependability without seriously increasing their cost.

This study, then, is intended to establish the effectiveness of smoke alarms, evaluate the costs and benefits of extending their use to houses that do not currently have them, and consider ways of improving their dependability in use.

As in the preceding sprinkler study, this study is concerned with one and two family houses across Canada. The authors are indebted to the provincial fire marshals and fire commissioners for providing statistical data on the fire performance of such houses with and without smoke alarms. In particular, the data provided by British Columbia, Alberta and Ontario proved to be extremely valuable.

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ISOLATING THE EFFECT OF SMOKE ALARMS IN IMPROVING FIRE SAFETY

While smoke alarms have been acknowledged to be an important element in fire safety, other factors are also important. The number of occupants, their age distribution, gender, living patterns, educational level, income level, ethnic background, cigarette, alcohol and drug use, all appear to have influence on the resulting level of fire safety. The building as well as the occupants can also play a role. The flammability of the upholstery, bedding, drapery and clothing fabrics, and the available egress routes can affect safety although these are considered to be of secondary importance compared to the living patterns of the occupants. Although the period of construction of the house appears to be indicative of its relative safety as shown in the CMHC sprinkler study, the relatively good fire record of newer houses may also be due to factors related to the socio-economic profile of the occupants of newer houses, and certainly to the use of smoke alarms as well as the condition of the house.

Several of these factors have been changing in recent decades, making it difficult to isolate or ascribe the role of any one in causing the improvement in fire safety in houses. As particular examples, both cigarette smoking and the number of children in the home have decreased. Both changes must have helped improve fire safety fractionally, reducing the significant portion of fires for which they are generally indicted. (The children cited particularly because of playing with matches and lighters, as was noted in the CMHC sprinkler study). The wider use of less flammable textiles has also reduced the still-substantial role of bedding, upholstery and the like. Conversely, it appears that the changing habits of drug use are playing stronger roles in fire incidence and fatalities, and the safety performance of houses has improved despite that.

In any case, it is difficult to infer that all of the steady improvement in house fire safety has been due to smoke alarms, in the midst of the improvement in several other significant factors, and keeping in mind the great differences in these factors in the various housing and socio-economic strata.

The approach followed here, then, is to trace the housing stock performance only over the short time span from when most of the stock did not have smoke alarms to when most of it did: 1980 to 1987. None of the other fractional effects (fractional, in that each of them is considered to cause only a minor fraction of fires) would itself have changed much in that short time. The single change in kind was the adoption of smoke detectors; that alone must be credited with almost all of the multifold improvement in house fire safety of the last several years.

SMOKE ALARM USAGE AND CONCURRENT HOUSE FIRE DATA

Current Use of Smoke Alarms

As noted earlier, smoke alarms, according to a May, 1988 sampling by Statistics Canada, are used in about 83% of owner occupied households and in 74% of tenant occupied households. Unfortunately, these statistics do not differentiate between one and two family houses and other types of housing units. Since the majority of one and two family houses are owner occupied, it was decided to weight the assumed proportion in favour of the latter. It was assumed therefore that 82% of one and two family houses in 1987 had smoke alarms, the same as that estimated for U.S. households that year (4). Of the estimated 6.188 million one and two family houses in Canada in 1987 (2), it is estimated that about 5.074 million (82%) had smoke alarms and 1.114 million (18%) did not.

Smoke Alarm Reliability

The 1984 NBS cost benefit study of sprinkler systems estimated that the operating reliability of smoke alarms was 84.7% (5). This was based on previous field surveys. A 1988 NAHB/NRC cost benefit study selected the same reliability estimate, and suggested that this was in agreement with a 1987 survey of the Dallas area (6). According to the National Fire Protection

Associations's analysis of data from the U.S. National Fire Incidence Reporting Service (NFIRS), only 68% of the alarms in houses and mobile homes that reported fires in 1986 were operational (4). Whether this is indicative of the total house population must be questioned, since defective alarms were undoubtedly a significant factor in allowing fires to develop to a reportable state, as will be seen. Local studies referenced in (4) indicated that alarm reliability in the general housing stock varied from 75 to 66%.

While the operational condition of smoke alarms in houses where fires were reported seems fairly well substantiated, that of the general housing stock seems less well documented. In consideration of the fact that housing with reported fires may well have a greater percentage of defective smoke alarms than the general housing stock, it was decided to select a reliability factor for the general housing stock somewhere between the 84% assumed in the U.S. cost-benefit studies, and the 68% indicated for houses reporting fires. An average operating efficiency of 75% was therefore selected as being a reasonable compromise between the two extremes. Since the vast majority of smoke alarms in the general housing stock are of the battery operated types, it was considered that this value should be representative of such units. Where wired-in alarms are used, however, experience with Ontario Housing Corporation housing (as reported in the CMHC sprinkler study (2)) indicates that a reliability of about 97% is an appropriate assumption.

Canadian Fire Data

No national data base is available in this country to compare the number of fires, fatalities, injuries and property losses in houses with and without smoke alarms. Most provinces apparently do not collect such information.

Requests to various provincial fire marshals and fire commissioners for such data resulted in responses from Alberta, British Columbia and Ontario, who supplied yearly comparative data for the period from 1984 to 1988.

British Columbia and Alberta data have separate categories for fires in which the existence or performance of the smoke alarm is not known. Ontario statistics are not differentiated: if smoke alarms are not mentioned in the fire reports, it is assumed that no smoke alarms were present. The Ontario statistics probably give slightly inflated values for houses without detectors and deflated values for houses with detectors. This is not considered significant, however, since the percentage of fires in which the presence of an alarm is unknown is small, as indicated by the B.C. and Alberta data. Since by far the greatest proportion of fires is reported in houses not equipped with alarms (4), it should cause minimal error to include this unknown category with the houses without smoke alarms.

Tables 1, 2, and 3 summarize the data provided by the three provinces, comparing the fire records of houses with and without smoke alarms on a year to year basis from 1984 to 1988. Table 4 consolidates this data over the 5 year period. Table 5 also summarizes this data but, in the case of Alberta and B.C., data were deleted for those fires where the alarm status was unknown. This was not possible with the Ontario data, for the reasons previously stated. In Table 6, also a 5 year summary of data, the category for which the alarm status was unknown is grouped with houses without alarms. For ease of comparison, both Tables 5 and 6 are shown in percentages.

It may be seen by comparing Tables 5 and 6 that grouping the data for houses with unknown alarm status with the houses without alarms has relatively little effect on the percentage value in all categories except the number of fires. In making this grouping, however, the values for Alberta and British Columbia are brought closer together.

Nevertheless there is a significant difference from province to province. While this may be due in part to normal statistical variations, it could also reflect the degree of accuracy of the data collection. Statistics, of course, should not be taken at face value. When compiling such data from a variety of sources it is important that they reflect the same type of data. While it would have been of interest to have investigated the reasons for the differences between the provincial data, this was simply

not possible with the resources available for this project. Table 7 lists the data from the three provinces for fires in which the houses were known to have alarms. It compares fire records of houses where the alarm sounded to those where the alarm did not sound.

FIRE FATALITIES PER REPORTED FIRE...AND PER HOUSE YEAR

Table 8 compares the data from the three provinces on the basis of the rate per reported fire of deaths, injuries and property losses. This table shows some anomalies that are at first puzzling. It shows that in terms of injuries and property loss, the rate per reported fire is higher in houses without alarms than in houses with alarms in BC and Ontario, as expected. In Alberta, however, it is less. Smoke alarms of course do not prevent fires, but they do clearly reduce the number of fires that are allowed to become serious enough to be reported. This is probably the reason why the values per reported fire are larger in these categories in certain houses with alarms. In fatality rates, however, all provinces show reductions per fire - but much greater reduction per house year, which is the final fact of safety performance. This apparent anomaly is evaluated and resolved in the following pages.

As previously noted, the current use of smoke alarms generally parallels US usage. If it is assumed that Canadian adoption of smoke alarms has been similar to that of the US over the 1984-1988 period, then US smoke alarms statistics can be used to estimate the population of Canadian houses with and without alarms during this period in which Canadian data is unavailable. The usage has been estimated at 74% of US houses in 1983, increasing to 82% in 1987, or an average of 77% over the 5 year period (4).

An estimate of the number of 1 and 2 family houses is given in Table 9. This is based on Canadian statistics for single family houses with an appropriate allowances for 2 family houses, based on past construction patterns.

Based on these housing stock estimates and on the assumption that during this period smoke alarms were in use in an average of 77% of the houses, it was calculated from Table 4 that the incidence of reported fires in houses without smoke alarms was about 10.8 times greater than in houses with alarms. When this is taken into account in analyzing Table 8 it can be readily seen that the fatality, injury and loss rates per house is very much less in houses with alarms regardless of whether or not the alarm operated during the fire. Clearly, the households still lacking alarms are distinguished from the alarm-fitted stock in other ways than their lack of the alarm. This will be explored later.

Statistics issued by the Fire Commissioner of Canada showed that there were 442 fire fatalities in one and two family houses in 1980; the number gradually dropped to 277 in 1987. Based on U.S. data, about 22% of the houses in 1980 had alarms and 82% in 1987 (4). During this period, the number of housing units increased from 5.575 M units to 6.188 M.

Fire Fatality Rates Decreased

From these data, it can be calculated that the fatality rate for houses without detectors was about 92 persons per million houses, and for houses with detectors about 34.4 persons per million houses. (The method of calculation is given in Appendix A). This represents a 62% decline in the fatality rate.

Unfortunately, national fire statistics for 1 and 2 family houses are not available prior to 1980 although overall fire fatalities are. It is therefore difficult to check the actual fire fatality rate for 1 and 2 family houses before the general introduction of smoke alarms. It is possible, however, to develop a reasonably close estimate based on the ratio of fires in 1 and 2 family houses to the total number of fire fatalities from later data.

During the period from 1980 to 1985, for example, fires in 1 and 2 family houses were about 57% of the total number of fires. In 1976 the total number of reported fatalities was 856. If 57%

were in 1 and 2 family dwellings, this would be about 488 fatalities. Since the stock of 1 and 2 family houses in 1976 was about 4.592 million, this meant that the fatality rate was about 106 persons per million houses. This compares reasonably well with the fatality rate of about 92 persons per million calculated for houses without alarms as per Appendix B.

The smoke alarm data from the 3 reporting provinces in Table 4, on the other hand, indicates that for the 1984-88 period, the annual fatality rate in houses with alarms was approximately 8.2 persons per million houses, while in houses without alarms, the rate was about 149 persons per million houses (about 18 times higher). The average fatality rate for all houses during this period was about 40.7 persons per million houses or about 5 times higher than for houses with alarms.

The fatality rate of 149 persons per million houses seems very high when compared with the values calculated for houses assumed to have no alarms using the method outlined in Appendix B. It is suggested that the residual portion of housing still without alarms is in a considerably higher risk category than other houses. Households that have not yet thought to install alarms, or have not been able to, must often differ from the general case in attitude, advantages or housing condition, or in all three.

On the other hand, the fatality rate of 8.2 persons per million houses with alarms in Table 4 seems low in light of the data in the CMHC sprinkler study previously referred to. In that study, a fatality rate of 14 persons per million houses was estimated from newer houses assumed to have wired-in alarms. Since alarms in general usage are battery type with generally lower operated efficiency, it would be expected that the fatality rate in Table 4 would show an even higher fatality rate than 14 persons/million houses for alarm equipped houses.

There is a suspicion, therefore, that the fire data in Table 4 may have over estimated the effect of smoke alarms, possibly by under counting the presence of smoke alarms in more serious fires where their presence could not be easily established. The much lower fatality rate between houses with and without alarms indicated in U.S. data (108.1) tends to support this (4).

Effect of Alarms in Reducing the Number of Reported Fires

Care has to be taken in applying any statistics to avoid incorporating significant biases. For example, comparisons of fire events in relation to reported fires ignores the fact that in houses where smoke alarms operated, early fire detection allows many fires to be extinguished before they are large enough to require firefighter assistance, and therefore go unreported. By comparing the performance of houses with and without alarms per reported fire, the true effect of smoke alarms will be greatly underestimated. This must be taken into consideration in analyzing the data in Table 4 and 8.

Since smoke alarms do not in themselves reduce the number of fires, but only the number of reported fires, it can be assumed that the number of total fires per house is the same with or without the alarms, other things being equal. Therefore any reduction in reported fire events will be proportional to the number of houses if allowance is made for those fires that would have become serious enough to report had there not been an early warning.

An estimate of the effect of early warning in reducing the number of reported fires can be made as follows: If it is assumed that the early warning provided by alarms was the principal reason for the declining number of reported fires from 1980 to 1987, and that the use of smoke alarms increased from 22% to 82% in that period, it can be shown that the number of fires reported in houses without alarms is about 2.2 times greater than in those with alarms (Appendix A). That is, with alarms, only about 45% of potentially reportable fires are in fact reported.

In reviewing Table 7, it may be noted that the number of fires reported in houses with alarms was 12,567, and 6326 (50.3%) of these occurred in houses where the alarm sounded. As previously noted, U.S. data indicates that in houses where fires were reported, about 68% of the alarms were operational and 32% were not. Assuming this relationship is the same in Canada, it can be shown that the number of alarms that went unreported is equal

to (0.62 x 12,567 - 6362)/0.32 or 6936. This number of fires that went unreported is about 1.09 times those that were reported when the alarms operated. In other words the number of fires reported for houses with alarms is about 48% of the total that would have been reported if an alarm had not been given. This is in good agreement with the above estimate based on the method in Appendix A.

Further Estimate of Fatality Reductions from Field Data

One drawback in using the data in Table 4 to estimate the effect of installing alarms in reducing fatalities is that houses still without alarms are broadly in a higher risk bracket, for several reasons, than houses with alarms. By using Table 8, however, it is presumed that a more accurate estimate can be made of the effect of early warning since all houses were initially equipped with alarms, and only the effect of early warning is being compared.

In Table 8, the fatality rate for houses in which the alarms operated was 0.0068 per reported fire and 0.01091 where the alarms did not work. Based on previous estimates of the number of reported fires (assuming 68% of the alarms were operational), the adjusted fatality rate should be 0.00680/2.09 or 0.00325 lives per fire. In other words, the smoke alarm warning appeared to reduce the fatality rate by about 70%. Since the fatality sample is fairly small, such a large reduction estimate should be reviewed skeptically, especially in the light of the 62% overall reduction estimated based on the procedure in Appendix A.

Theoretical Estimates Of Fatality Reduction Per Fire

Although relatively little research has been undertaken to assess the effectiveness of smoke alarms in saving lives in actual fire conditions, one significant study was undertaken in the early 1960's by Canadian researchers who examined the circumstances involving 342 fatalities in residential fires (7). It was estimated that had smoke detectors been present, about 41% of the

lives could have been saved. This study, while subjective, was one of the first significant attempts to assess the effectiveness of smoke alarms and provides a useful comparison with other estimates. The 41% estimate assumed all alarms worked. In these and the following theoretical studies, the point that most fires would in fact be quickly extinguished and not reported, with the use of alarms, was not anticipated.

Theoretical studies have also been undertaken by the U. S. National Bureau Standards on the effectiveness of smoke alarms based on their response characteristics in typical fire scenarios. A comprehensive fire loss model developed by NBS describes a decision analysis framework for evaluating different procedures for reducing fire losses. A preliminary report considered the effect of smoke alarms, sprinkler systems and a combination of the two (8). Although the final version of this model does not appear to have been published, its methodology was used to estimate the effect of both smoke alarms and residential sprinkler systems in a 1984 NBS cost benefit study of sprinklers (5). The fire loss component of this model was used to estimate potential reductions in life loss, personal injury and property loss due to the installation of smoke alarms and residential sprinkler systems. The procedure takes into account statistics and makes judgemental decisions to evaluate typical fire scenarios, including the operating characteristics of smoke alarms.

On the basis of this model, NBS estimated that the use of detectors in the event of fire should reduce fatalities by about 52%. This study assumed an operating efficiency for the alarms of 84.7%. which, as indicated earlier, may be somewhat high for battery type units and low for wired-in units. Assuming 75% and 97% reliability factors are used to represent battery and wired-in units, the adjusted reduction in life loss would be about 46% and 59% respectively.

In a second NBS study that confined itself to the effectiveness of smoke alarms and sprinkler systems on life safety only, data was used from NFIRS and other sources to develop a comprehensive model that also took into account typical fire scenarios, the location and mobility of the occupants, and the response time of

the smoke alarms (9). It was estimated that if all alarms were operable, there would probably be a reduction in life loss of about 50%. Assuming a 75% reliability, therefore, this estimate would be reduced to about 37%. For 97% reliability, the reduction would be about 49%. Again, these studies appear to miss the retrospective point that the smoke alarms first save lives and property by allowing most fires to be extinquished quickly and never reported.

Concluding Judgement on Fatality Reductions Due to Smoke Alarms

Since 20 to 30% of fire fatalities are considered to be virtually unpreventable, in various studies, due to the nature of the fire, its intimacy with the victim or the victim's lack of mobility, there is obviously an upper limit to the maximum reduction factor attainable (9) with smoke detectors or sprinklers. This will be raised again at the conclusion of this study.

In view of the 62% and 70% reductions estimated respectively in Appendix A and from Table 2, but recognizing that factors in addition to smoke alarms also contributed somewhat to the decline in fatalities, the judgement is taken that battery-operated smoke detectors offer about a 55% reduction in fire fatalities in houses.

Where wired-in detectors are used (or where battery operation is always maintained) the fatality reduction is then estimated at (55x.97/.75) 71% because of reliability. That's too close to the theoretical upper limit suggested before; the judgement taken here is that wired-in alarms reduce fatalities by about 65%.

EFFECT OF EXTENDING SMOKE ALARM USE TO STILL-UNPROTECTED HOUSES

Since the probable reduction in fatality rates due to smoke alarms has been established, it is possible to estimate the probable number of lives that can be saved in houses currently without alarms, if the current fatality rate of the latter is known.

According to the method described in Appendix A, the fatality rate for the housing stock with alarms is 34.4 persons per million houses, and 92 persons per million houses for those still without. In the CMHC sprinkler study, however, it was estimated that the fatality rate in newer houses equipped with wired-in alarms is about 14 persons per million houses. If the fatality rate varies in direct proportion to the operational efficiency of the alarms, the rate for houses equipped with battery type units should be 14 x 0.97/0.75 or about 18 persons per million houses. Since the estimate is based on newer houses, it is expected that the rate for the general population of alarm equipped houses would be higher.

Data from the three reporting provinces (Table 4), however, showed fatality rates of 8.2 and 149 respectively for houses with and without alarms. Based on the preceding estimates, the 8.2 value seems excessively low, even when allowance is made for the fact that the national fatality rate for houses is about 22% higher than for the three provinces. As noted earlier, however, the total number of fatalities in alarm equipped houses is low (111) and this is probably too small a sample for statistical reliability. It seems reasonable to conclude therefore that the annual fatality rate for the general population of houses currently with smoke alarms is between 18 and 34 persons/million houses.

The fatality rate estimated for alarm equipped houses using the procedure in Appendix A may be somewhat high due to the fact that it is largely based on the reductions that occurred in houses with less risk. On the other hand, the fatality rate estimate for alarm equipped newer houses is probably too low for older houses.

It was therefore decided to select a compromise value midway between these estimates, or 26 persons/million houses. Based on the assumption that this represents 82% of the housing stock, the annual fatality rate for houses still without alarms may be about 130 persons per million houses. A 55% reduction in this rate as a result of installing battery operated alarms represents about 72 lives saved annually per million houses. Wired-in units might increase that to 85 lives (saving 65%).

Fire Fighter Fatalities

In the CMHC sprinkler study, statistics indicated that the ratio of fire fighter fatalities to civilian residential fire fatalities was about 1 to 74 or about 0.013. Assuming that this relationship holds true, it is estimated that installing alarms would annually save about 1 fire fighter life per million houses, again considering that stock which has remained unprotected.

INJURY RATES AND SMOKE ALARM USAGE

The NBS model for estimating the effect of smoke alarms in fire safety, and used as the basis for the NBS cost benefit study of sprinklers, was used to estimate the effect of smoke alarms on injuries and fire damage (8). According to this method, the use of smoke alarms should reduce the injuries per fire by about 5% assuming a smoke alarm reliability of 84.7%. This is in contrast with an 8.3% increase in injuries per fire reported in NFIRS data (Table 17 of reference 6). The latter is on the basis of reported fires. Returning to the earlier discussion for the moment, the alarm may often allow a fire to be extinguished quickly and never reported. Only those not readily extinguishable become serious enough to be reported, and those are more apt to entail injury. (Further, people who would have become fatalities are now merely injured: as fatality numbers decrease the injury numbers tend to increase.)

Considering the house, not the reported fires: if the Canadian

injury rate in 1980 is compared with the rate for 1987 in relation to the increasing use of smoke alarms (see Appendix A) it will be seen that the use of smoke alarms reduced the injury rate per house by 12%. This assumes that all the reduction was due to the smoke alarms. If the alarms were wired-in or otherwise continuously operative, the reduction would be 13%.

Based on the cost per injury of $30,000 assumed in the CMHC sprinkler study, the average cost per injury per house in the general housing stock in 1987 was $6.84 for houses without alarms and $6.02 for houses with alarms, assuming that the use of alarms reduce the injury rate by 12%. Since fire fighter injuries are about 1/3 the civilian rate, the cost of such injuries is estimated at $2.28 for houses without alarms and $2.01 for those with alarms, annually.

PROPERTY LOSSES AND SMOKE ALARM USAGE

The true effect of smoke alarms on property losses is difficult to assess since, as previously noted, very many fires are detected in earlier stages and are extinguished by the occupant. These tend to be unreported events, with presumably some damage in some cases. In addition, fire loss estimates also reflect the value of the property and are not necessarily a true measure of fire severity. The 18% of the houses without alarms have a disproportionate population of poorer quality houses. (The increased fire risk of disadvantaged households was discussed in the CMHC sprinkler study and has been the subject of other studies as well (10)). The loss from the destruction of a new house, for example, is generally much higher than for the destruction of a slum house. This subject will be discussed later in assessing the costs and benefits of smoke alarms in new houses alone.

If the true effect on property loss reductions (due to the early warning provided by alarms) and the current damage in houses without alarms can be determined, then it is possible to estimate the savings per house to be gained by the installation of smoke

alarms in the 18% of the houses currently without them. If the annual reduction in national fire losses is examined in the light of increasing use of smoke alarms as described in Appendix A, it can be shown that houses without alarms had an average loss of $79.30/house, while those with alarms had a loss of $40.20/house, implying a saving of $39.10/house. As previously noted, there are often other contributing factors to reduced fire losses even though the use of smoke alarms must be the principal one. On the other hand, since the loss comparisons here are based mainly on better quality houses (i.e. those with alarms), where their individual damage estimates tend to be higher than for those without alarms. On the whole, it is difficult to estimate whether the reduction per house is under or over estimated by this method.

If the losses for the 3 reporting provinces in Table 8 are compared, the loss per reported fire is $16,980 for houses with working alarms and $11,961 for houses with nonoperating alarms. The estimated loss per fire incident should be reduced to $16,980/2.09 or $8,124. (As before, the factor 2.09 represents that the actual number of fires are more than double the reported fires, when alarms are operative.) This represents a 32% reduction in annual fire losses for an alarm equipped house. If it is assumed that the saving varies in direct proportion to the operational reliability, then with wired-in alarms the reduction should be 32x0.97/0.75 or 41.3%.

(According to the theoretical model developed by NBS and used in their cost benefit study of sprinklers (5), the property loss per fire should be about 22% less in alarm-protected houses than in unprotected houses, and this is intended to apply to all fire events, not just those that become reported. As previously noted, this study assumes an alarm reliability of 84.7%. For 75% alarm reliability the reduction factor should be reduced to 20% while for 97% reliability, it should be increased to 25%)

According to Table 4, about 25.1% of the total property loss occurred in alarm-protected houses and 74.9% in unprotected houses. Over this period it is estimated that there were smoke alarms in an average of 77% of the houses. This indicated that the fire damage per unprotected house was about 10.4 times as

great as in houses with smoke alarms. (But again it must be noted that the residual, unprotected stock is undoubtedly below average in condition and household safety status.) Assuming that this ratio is constant and applies across the country, if the alarms were installed in 82% of the houses (1987) the losses should be adjusted from 25.1% to 30.5% occuring in the alarm-fitted stock.

It may be of interest to compare this with 1984 NFIRS data representing over 132,000 fires. This indicates that 25.0% of the total damage occurred in houses protected with smoke alarms, which at that time, were estimated to be in 75% of the houses.(6) This is fairly close to the estimate based on Table 8. Assuming that fire losses are distributed in the same proportion across the country, the damage to houses currently without detectors can be estimated using these values.

Since the total national loss for 1987 was $277 M (Appendix A) the portion occurring in alarm protected houses is estimated as 30.5% of this or $84.5 M. The remainder, $192.5 M is assumed to occur in unprotected houses. This is approximately $16.65 and 172.80/house respectively for protected and unprotected houses. Assuming a 32% reduction from battery type alarms, the estimated saving per house is calculated as 0.32x172.80, or $55.30/house. If the savings indicated by the NBS study were used instead of those determined from Table 4, the savings per house would be about 0.195x172.80 or $33.70/house. As a compromise estimate, the annual property saving gained by smoke alarms may be taken as about $45 per house. (If wired-in alarms are used, it is assumed that the saving will be in proportion to the operational efficiency (i.e. $45x0.97/0.75) for a saving of $58 per house.)

OTHER SAVINGS

Indirect Costs

In the CMHC sprinkler study, it was estimated that the total indirect cost per house as a result of fire was about $2.90 per house, with or without smoke alarms. The indirect costs were about 6.5% of the direct costs. If it is assumed that the

relation between direct and indirect costs is constant, then the indirect cost savings would be 0.065 x $45 or about $2.93 per house, based on 75% alarm reliability. (Or $3.77 for 97% reliability)

Fire Service Costs

The CMHC sprinkler study considered the possible effects of safer houses on municipal fire services. The point had been made that if sprinklers were to reduce the demands on the fire services there should eventually be attendant savings in service costs. That claim could have been made more emphatically about the earlier, and therefore more effective, introduction of smoke alarms. The incidence of reported fires - those needing professional attention - has been reduced drastically. Nevertheless the fact is that there has been no reduction in fire service costs in that period of sharply reduced incidence of fires. As noted in the CMHC sprinkler study, there is evidence of greater per capita spending on fire services in spite of increased fire safety in houses. The reasons for this are not known with certainty but it would seem that the increasing role of fire services in activities other than fire fighting is an important factor, as is the increasing public expectations of still greater safety.

In view of these considerations, it was decided that there should be no allowance made for reduced fire fighting services even if the remaining 18% of the houses were to be equipped with alarms. The net result of the reduced demand on present fire services would in all probability be a doubly-enhanced level of fire protection with no resulting reduction in costs.

A summary of the risk assumptions used in calculating the costs and benefits of alarms in those houses currently without them is shown in Tables 10 and 11.

SMOKE ALARMS IN NEW HOUSES

Life Safety Effect of Smoke Alarms in New Houses

No formal cost-benefit study was carried out prior to the adoption of requirements that mandated the use of wired-in smoke alarms in new buildings in the 1980 edition of the National Building Code. Retrospectively, it is useful to assess this from the records if only to provide a yardstick against which other fire safety features may be compared. In the CMHC sprinkler study, the annual fatality rate for houses with wired-in smoke alarms (i.e. newer houses) was estimated to be 14 persons per million. Earlier in this study of smoke alarms it was calculated that wired-in alarms should reduce the fatality rate by 65%. If such alarms were not installed in new houses, the fatality rate would probably be 14/(1.00-0.65) or 40 persons per million houses. Smoke alarms are probably saving 26 lives per million newer houses.

This is much less than the estimated saving of 75 lives previously predicted for installing wired-in alarms in those houses that still lack them, and illustrates the relative risks presented in the two groups of houses.

Injuries In Newer Houses

Data for newer houses in the CMHC sprinkler study indicated that such houses had about 10% fewer injuries than the general housing stock. Since these houses were equipped with wired-in smoke alarms, it was assumed that this was the principal reason for the difference.

Assuming the average injury to cost about $30,000 as discussed earlier, and that the fire fighter injury rate is about 1/3 of the civilian rate, it can be calculated that the average injury cost per house for the entire housing stock is about $8.45 per house. Since new houses are 10% less than this, the injury cost per new house is calculated as $7.61 per house. Since the installation of a wired-in alarm was previously determined to

reduce the injury rate by 13%, it is estimated that if such alarms were not installed in new buildings, the injury cost would be $7.61/(1.00-0.13) or about $8.75/house, for a saving of $1.14.

Property Losses in New Houses

Although little apparent statistical differences were indicated in the CMHC sprinkler study in the property loss per house between newer houses with wired-in alarms and the general housing stock, this was due to the higher cost of repairs or replacement of newer houses. (The relatively small size of the statistical sample could also have been a factor.)

Tables 12 and 13 show the number of fires in British Columbia and Alberta in newer houses as well as the general housing stock. Like other data for newer houses that formed the basis for many of the conclusions in the CMHC sprinkler study, the "newer" houses were those constructed in the 5 year period previous to the year of the fire record. Tables 14 and 15 are similar except that the "newer" houses include those constructed during the year of the fire record and the four previous years. This second data base was established to make use of as much recent fire data as possible in an attempt to make the statistical sample larger. This was the same procedure followed for other fire records in the CMHC sprinkler study.

Table 16 combines the fire loss data from Tables 12 to 15 and accumulates them from year to year. Table 17 shows similar data for the general housing stock in British Columbia and Alberta and compares the fire rate in newer houses to the general stock.

Table 18 combines the fire loss data from Phase 2 and the number of fires from Table 16 to estimate the average loss per fire. Finally, Table 19 shows the average property losses in the general housing stock and compares these to the losses recorded for newer houses.

It will seem from Table 17 that, if only those houses constructed in 1981[1] or later are considered (i.e. with wired-in alarms), the fire rates per house are 63 and 65% of the rate for the general housing stock, depending on the data base. In effect, therefore, the newer alarm equipped houses had about 35% fewer reported fires per house than the general housing stock.

Similarly, in Table 19, the property loss per fire in newer houses (1981 or later) is from 71% to 45% greater than the general housing stock, again depending on the data base.

The appreciable difference in the results for the two data bases is due to the erratic nature of property loss estimates which seem to fluctuate more widely than other fire data. This is presumably due to the subjective nature of such estimates. For the purpose of this phase of the study, the property loss per fire was assumed to be 50% greater in newer houses than in the general housing stock.

The lower rate of recorded fires in newer houses could be due to the lower fire risk factor inherent with new houses and their occupants or it could be due to the effect of the smoke alarms, or a combination of both. At this stage, however, it is not feasible to differentiate between the relative effects of these factors.

The reduction in the number of reported fires along with a 50% increase in the cost per fire, work together to cancel out any apparent difference in property loss per house between newer houses and the general housing stock.

Assuming that the data for British Columbia and Alberta will reflect the same trends as in national data (which does not differentiate between newer and older houses), an estimate can now be made of the possible effect of smoke alarms on property losses.

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[1] It is assumed that with the introduction of requirements for wired-in smoke alarms in new houses in 1981, houses built in or after this year are all equipped with wired-in smoke alarms. This was the same assumption made in the CMHC sprinkler study.

The average property loss per house in Canada in 1987 was $44.80 (Appendix A). This is therefore assumed to be the fire loss per house in newer houses for the reasons previously discussed. In the assessment of older houses it was estimated that the reduction in fire losses when wired-in alarms are installed is about (25+41.3)/2 or 33.2%. Therefore, if wired-in alarms had not been installed in the newer houses, the resulting fire loss per house would have been $44.80/(1.00-0.33) or $67.07. This is a saving of $22.27 per new house as a result of wired-in alarms. It will be noted that this is considerably less than the $57.55 per house calculated for older houses with wired-in alarms, and is an indication of the much lower rate of fire incidence in newer houses even though the damage per fire is considerably greater.

Assuming that the indirect fire losses are 6.5% of the direct costs as noted in the CMHC sprinkler study, then the savings in indirect costs would be 0.065x22.67 or $1.47 per house.

A summary of the benefits of installing smoke alarms in new houses is given in Table 20.

IMPROVING THE EFFECTIVENESS OF SMOKE ALARMS

As noted earlier, U.S. fire records show that about 32% of the smoke alarms were inoperative in houses that had reported fires (4). One study has shown that about 61% of alarm failures were due to dead or missing batteries, or to power source problems. A further 36% of the failures were due to improper installation. Of the latter, improper location was the cause in 26% of the cases (4).

It would appear, therefore, that there is significant room for the improvement of detector reliability if steps could be taken to reduce power source problems and improve installation practices.

Battery Replacement Reminder

Where smoke alarms have audible weak-battery indicators, there is a temptation to remove the batteries to stop this annoyance, particularly if there is no spare battery on hand when the signal is initiated. The occupant may then forget to replace the battery since there is no longer a reminder signal. It may be appropriate therefore to consider replacing such audible signal indicators with a visual indicator such as a flashing light. In addition, when batteries are removed from the detector this should also be visually indicated. One way would be to make the closing of the smoke alarm cover impracticable unless the battery is in place. The use of at least three alarms, as advocated later, will help maintain coverage while one is awaiting its new battery.

Placement to avoid false alarms

A second concern is the effect of bothersome false alarms caused principally by improperly located alarms. Alarms located too close to a bathroom, for example, may be activated when the bathroom door is opened after taking a bath or shower. The excessive moisture can cause the alarm sensor to activate and initiate a false alarm. Similarly, an alarm located too close to a cooking area can be activated by smoke or steam from cooking.

Unless the alarm is equipped with a temporary shut-off (which automatically re-sets) the battery must be removed to deactivate it. The inconvenience of having to do this while the excess moisture or cooking smoke clears, encourages occupants to simply leave the battery out. Similarly, the lack of a temporary silencer for wired-in units may lead to their permanent disconnection.

In summary, therefore, education to ensure that alarms will be properly located to reduce the probability of false alarms, and/or the use of a temporary silencing device, should remove the temptation to remove batteries or disconnect the units.

More Alarms For Better Coverage

Another area in which the effectiveness of alarms could be improved is in the extent of alarm coverage. Both wired-in and battery alarms deserve more thought on this point.

The National Building Code, which is used as a model by most provincial and municipal agencies for new construction, requires that each sleeping area be protected by a smoke alarm which is generally located in the hallway serving the bedrooms. The NBC requires that such alarms be wired to the electrical supply, and where more than one alarm is required, they must be interconnected so that all will sound at the same time. The National Fire Code, which is used as a model code for fire safety in existing buildings, has essentially the same requirements but permits the alarms to be battery operated and not interconnected. This is due to the increased cost that would be required to have wired-in alarms installed after the building is constructed. Under both requirements, therefore, only one alarm needs to be provided if the sleeping areas are on one floor and served by a common hallway. (Ontario, however, has additional requirements).

It appears that this degree of coverage is not adequate. It has been shown in simulated fires that smoke alarms should be provided on each storey to ensure adequate escape time for the occupants (5). If the alarms are located on only one level in a multi level-house, therefore, they will not always be effective in saving lives.

U.S. data indicates that about 41% of fatal fires originate in the living room, while 27% originate in bedroom areas (Appendix A of reference 11). It would seem logical, therefore, to require a smoke alarm for the living area to protect the occupants who may occasionally sleep there, regardless of whether or not that storey has formal sleeping rooms.

U.S. data also shows that only 3% of fatal fires occur in heating equipment rooms, and 4% in storage areas. Since the majority of U.S. houses do not have basements, it is difficult to translate these data to Canadian houses. In addition, the Canadian heating

season being longer than in the U.S. may tend to produce higher fatality rates.

Alberta statistics indicate that about 20% of house fires originate in basements while those of Ontario show 28% (12). While these values do not distinguish between fatal and non-fatal fires, they nevertheless show that a substantial number of fires do originate in basements. While they may not be as lethal as fires that originate in bedrooms or living rooms, the relatively high number of fires would indicate that substantial damage must be the result. This fact alone, apart from the potential savings in lives, may well justify the installation of smoke alarms in all basement areas, particularly in view of the fact that these areas may be unoccupied for long periods even during the day. It is difficult, however, to estimate with any accuracy the actual cost effectiveness of such additional coverage, since there is insufficient data to permit a credible cost-benefit assessment. The low cost of smoke alarms would intuitively suggest that such installations would be justified: the basement should be equipped.

In sum, most houses should have at least three smoke alarms: one each in the living area, sleeping area and basement.

Programs Justified To Improve Coverage

Any measure to increase the reliability or effectiveness of smoke alarms will, of course, be less cost effective for houses that are currently protected since such households tend to be in the lower risk category. Improvement in reliability of currently available smoke alarms should be considerably more cost effective when they are installed in the 18% of the houses without detectors. As noted earlier, the fire loss and fatality rate per still-unprotected house is many times higher so that a percentage increase in reliability in such cases should pay a much higher dividend than in houses currently protected.

While it is not possible on the basis of existing data to provide credible estimates of the extent to which smoke alarm reliability may be improved, either through product changes or increased

coverage, the proposed suggestions to increase such reliability are not expensive and represent only a nominal investment.

As noted in the CMHC sprinkler study, however, the poor have different priorities for their limited resources. Any increase in potential safety even for a nominal cost may not be voluntarily undertaken. A subsidized installation program may in fact be the only way in which a significant additional increase in fire safety may be achieved. The municipality should save money thereby; fire losses sustained by the lower income groups in the high risk portions of the housing stock may have to be paid from the municipal treasury through welfare assistance or new subsidized housing. The decreased fire losses and welfare costs resulting from smoke alarm installations should alone warrant the additional expense to the municipality for the installation and annual inspection of such alarms, quite apart from the humanitarian case to be made for saving lives.

COST OF INSTALLING AND MAINTAINING SMOKE ALARMS

The installed cost of wired-in smoke alarms has been reported to Alberta Municipal Affairs by Wiebe Forest Engineering Ltd. in October 1989, as part of their Cost Study of Sprinkler Installations for Residential Houses. (That study was the primary reference on costs used in the CMHC sprinkler study (2).) For a split-level house of 140m^2 floor area, the costs quoted for an unusually rigorous 8-detector installation ranged from $363 to $756, with the average being $490. The cost for a more typical, and ample, 4-detector installation for this house ranged from $226 to $486 with an average of $316. The costs for this house might be expressed as about $150 for the circuit and about $42 per installed detector, implicit in the average figures.

A highly respected Ontario builder reported costs for straightforward houses to Scanada in early 1990: $85 for the circuit plus $35 for each detector, installed and commissioned. The costs would be $225 for a 4-detector installation.

Battery-operated alarms - which work just as well as wired-in alarms if kept fitted with a working battery - have become inexpensive indeed. Even those fitted with a temporary disconnect feature, as advocated earlier, are available for $15 or so. Installed by the householder, with a spare battery on hand as well, these alarms might entail about $20 per unit.

Installation by tradesmen might raise that to $40 each, or less, if done in a retrofit program involving a number of houses in a locality and three or more alarms in each house.

Two or three cost factors are additional to the foregoing installation costs: detector replacement, regular verification of reliability, and battery replacement in the case of the battery-operated units.

Concerning the working life of the detector, the Ontario Housing Corporation has found that the required replacement rate was about 2% a year, in its extensive social housing stock, as reported from 1974 to 1982. (There was no rising trend. Unfortunately, OHC's regular reporting ended in 1982; a wealth of experience on wired-in detector performance may await collation and reporting.)

Concerning regular verification of reliability and replacement of batteries, the education of householders, service trades, salespeople and social workers would seem to be the best path to follow. It is difficult to assign a cost to this; those involved are present in the house in any case and have concerns about safety performance or good will of the house and the household.

SUMMARY AND CONCLUSIONS

The effectiveness of smoke alarms can perhaps be stated best this way: In the 18% portion of Canadian houses still without smoke alarms, the annual fatality rate remains extremely high, about 130 lives per million houses; this would be reduced by about 55%, saving about 70 lives per year per million houses, if the houses were fitted with battery-operated alarms to todays's usual standard of placement and operation. The cost per life saved would be nil, in that the alarms would pay for themselves very quickly through reduced property losses alone. Annual property losses would be reduced from about $173 per house to about $118 by such common usage of battery-operated alarms, saving $55. A more conservative estimate suggests a saving of about $45 per house per year in that stock.

If that still-unprotected 18% of Canadian houses were fitted instead with multiple battery-operated smoke alarms designed to encourage full-time coverage, todays's annual loss of 130 lives per million houses in that high-risk stock would be reduced by almost two thirds, saving about 85 lives per year. Again, the cost per life saved would be nil; reductions in annual property losses should be about $58 per house, conservatively.

About $40 to $80 will cover the installation of two battery-operated smoke alarms; the lower figure assumes "do-it-yourself" installation. Improving the alarms and increasing the redundancy of coverage to help ensure full-time protection might raise these costs to $80 or $160 respectively. Clearly, the opportunity to extend smoke alarm protection to the still-unprotected portion of housing stock, and to ensure that the protection is maintained, is one of the greatest life-saving and cost-saving opportunities open to society.

Moving to new houses, in which wired-in smoke alarms have been mandatory for several years, it can be seen retrospectively that their present record of 14 lives lost per year per million houses would still be about 40 were they without alarms; the alarms are saving about 26 lives per year per million new houses. Again, the costs per life saved is very small or nil, in that the alarms

are slowly but surely paying their way in annual savings in property losses alone of about $22 per house. The annual loss without them would be about $67 in the new stock, as against today's $45 per new house with the alarms. The cost for installing good coverage (4 detector) is about $225.

Finally, further opportunities to avoid fire fatalities were discussed in the CMHC sprinkler study (2) and can now be seen more clearly and given even more emphasis. Reconsider the postulation that, in actual house fires, some 20% to 30% of fire fatalities could not be avoided by any detection or sprinklering devices (reference 9, as mentioned earlier in this report). Clearly, this "hard core" of fire deaths must be addressed by correcting the causes of the fires. The key list is not long: less flammability in upholstery, bedding and textiles generally will defeat most of the cigarette fires; childproof or inaccessible match boxes and lighters are in the same order of importance; stove-top shielding or fire suppression devices could also be of considerable value in saving property and lives.

Smoke detectors have already made a vast difference and their further deployment can do much more, but the final steps for society should be to ensure that they are rarely needed.

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Table 1

Houses Known to Have Alarms

Province	Year	No. of Fires	Injuries	Deaths	Fire Loss
Alberta	1988	401	58	1	5,111,000
	1987	414	42	1	5,532,000
	1986	414	47	2	7,496,000
	1985	465	45	1	6,338,000
	1984	470	41	1	6,693,000
B.C.	1988	657	75	6	26,535,000
	1987	698	76	10	15,863,000
	1986	693	57	7	17,565,000
	1985	757	71	8	21,484,000
	1984	617	41	10	14,761,000
Ontario	1988	1607	200	10	19,266,000
	1987	1507	211	15	16,178,000
	1986	1445	191	8	15,151,000
	1985	1268	158	18	14,199,000
	1984	1154	141	13	11,988,000
Alberta	84-88	2164	233	6	31,170,000
B.C.	84-88	3422	320	41	96,208,000
Ontario	84-88	6981	901	64	76,782,000

Table 2

Houses With No Alarms

Province	Year	No. of Fires	Injuries	Deaths	Fire Loss
Alberta	1988	1020	59	15	12,681,000
	1987	1072	73	13	14,854,000
	1986	1118	79	22	16,995,000
	1985	1210	90	21	18,033,000
	1984	1213	75	18	15,623,000
B.C.	1988	838	95	29	17,794,000
	1987	931	73	12	17,807,000
	1986	1051	75	18	22,673,000
	1985	1552	124	39	38,325,000
	1984	1322	105	32	32,883,000
Ontario	1988	4929	443	61	77,510,000
	1987	4982	486	70	83,726,000
	1986	5436	531	75	71,630,000
	1985	5107	525	80	67,179,000
	1984	5066	497	75	61,253,000
Alberta	84-88	5633	376	89	78,186,000
B.C.	84-88	5694	472	130	129,482,000
Ontario	84-88	25,520	2482	361	361,298,000

* Statistics for Ontario for houses without alarms are based on fire fighter reports which do not mention alarms. These probably include those where it was not known if an alarm was present.

Table 3

Alarm Status Unknown *

Province	Year	No. of Fires	Injuries	Deaths	Fire Loss
Alberta	1988	82	13	2	3,297,000
	1987	88	11	4	4,105,000
	1986	70	7	3	2,930,000
	1985	53	10	2	2,724,000
	1984	48	4	3	3,938,000
B.C.	1988	572	4	2	4,526,000
	1987	593	8	0	4,452,000
	1986	784	10	5	6,059,000
	1985	905	1	0	6,533,000
	1984	344	1	0	1,914,000
Ontario**	1988	-	-	-	-
	1987	-	-	-	-
	1986	=	=	=	-
	1985	-	-	-	-
	1984	-	-	-	-
Alberta	84-88	341	45	14	16,994,000
B.C.	84-88	3198	24	7	23,484,000
Ontario**	84-88				

* Includes cases where alarm status could not be determined or whether or not an alarm had been installed.

** Ontario has no equivalent category – This is probably included with data for "Houses with no alarms".

Table 4

Comparative Data For One and Two Family Houses
(with or without smoke alarms)

Province	Smoke Alarm Status	Fires	Fatalities	Injuries	Losses * (Millions)
Alberta	with	2,164	6	233	$ 31.17
		(26.6%)	(5.5%)	(35.6%)	(24.7%)
	without	5,633	89	376	$ 78.19
		(69.2%)	(81.7%)	(57.5%)	(61.9%)
	unknown	341	14	45	$ 16.99
		(4.2%)	(12.8%)	(6.9%)	(13.4%)
	Total	8138	109	654	$126.35
		(100%)	(100%)	(100%)	(100%)
B.C.	with	3,422	41	320	$ 96.21
		(27.8%)	(23.0%)	(39.3%)	(38.6%)
	without	5,694	130	472	$129.48
		(46.2%)	(73.0%)	(57.8%)	(52.0%)
	unknown	3,198	7	24	$ 23.48
		(26.0%)	(3.9%)	(2.9%)	(9.4%)
	Total	12,314	178	816	$249.17
		(100%)	(100%)	(100%)	(100%)
Ontario	with	6981	64	901	$ 76.78
		(21.5%)	(15.1%)	(26.6%)	(17.5%)
	without	25,520**	361**	2482**	$361.30**
		(78.5%)	(84.9%)	(73.4%)	(82.5%)
	unknown	- **	- **	- **	- **
	Total	32,501	425	3383	$438.08
		(100%)	(100%)	(100%)	(100%)
Totals	with	12,567	111	1454	$204.16
		(23.7%)	(15.6%)	(30.0%)	(25.1%)
	without	36,847	580	3330	$568.97
		(69.6%)	(81.5%)	(68.6%)	(69.9%)
	unknown	3,539	21	69	$ 40.47
		(6.7%)	(2.9%)	(1.4%)	(5.0%)
	Total	52,953	712	4853	$813.60
		(100%)	(100%)	(100%)	(100%)

* 1989 dollars.

** Ontario statistics for houses with no alarms are based on fire reports which do not mention alarms. These probably include those where it was not known if a fire alarm was present. The values for houses without alarms, therefore are suspected to be slightly high and those with alarms slightly low.

Table 5

Comparison of Houses With or Without Smoke Alarms
(With unknown alarm status subtractive)

Province	With Alarms				With No Alarms			
	Fires	Injuries	Deaths	Loss	Fire	Injuries	Deaths	Loss
Alberta	27.8%	38.2%	6.3%	28.5%	72.2%	61.8%	93.7%	71.5%
B.C.	37.5%	40.4%	24.0%	42.6%	62.5%	59.6%	76.0%	57.4%
Ontario	21.5%	26.6%	15.1%	17.5%	78.5%*	73.4%*	84.9%*	82.5%*

* Ontario statistics for houses with no alarms are based on fire fighters reports that make no mention of smoke alarms. These probably include those where it was not known if an alarm was present thus making these values somewhat higher than warranted. By the same token the value for houses "with alarms" are probably on the low side.

Table 6

Comparison of Houses With and Without Smoke Alarms
(assuming all of the "unknown alarm status" statistics
apply to houses without alarms)

Province	With Alarms				With No Alarms			
	Fires	Injuries	Deaths	Loss	Fires	Injuries	Deaths	Loss
Alberta	26.6%	35.6%	5.5%	24.7%	73.4%	64.4%	94.5%	75.3%
B.C.	27.8%	39.2%	23.0%	38.6%	72.2%	60.8%	77.0%	61.4%
Ontario	21.5%	26.6%	15.1%	17.5%	78.5%	73.4%	84.9%	82.5%
Weighted Average *	23.7%	30.0%	15.6%	25.0%	76.3%	70.0%	84.4%	75.0%

* Weighted on the basis of the number reported in each program.

Table 7

Data For One and Two Family Houses With Smoke Alarms

Year	Event	Alarm sounded				Alarm Not sounded			
		Alta.	B.C.	Ont.	Total	Alta.	B.C.	Ont.	Total
1984		185	291	596	1072	285	326	558	1169
1985	No. of	201	434	668	1303	264	323	600	1187
1986		185	393	709	1287	229	300	736	1265
1987	Fires	182	386	743	1311	232	312	764	1399
1988		174	361	818	1353	227	290	789	1306
Total		927	1865	3534	6326	1237	1551	3447	6235
1984		1	2	3	6	0	8	10	18
1985		0	4	3	7	1	4	15	20
1986	Fatalities	1	6	6	13	1	1	2	4
1987		0	3	5	8	1	7	10	18
1988		0	3	6	9	1	3	4	8
Total		2	18	23	43	4	23	41	68
1984		14	20	93	127	27	21	48	96
1985		19	42	90	151	26	29	68	123
1986	Injuries	21	35	119	175	26	22	72	120
1987		13	57	118	188	29	19	93	154
1988		26	43	124	193	32	32	76	140
Total		93	197	544	834	140	123	357	620
1984	Loss (Millions	1.284	6.28	6.091	13.655	4.171	5.75	3.680	13.601
1985	of $) (not	1.467	10.44	8.598	20.505	3.909	7.77	3.443	15.122
1986	conv. to	2.619	8.66	8.596	17.175	4.039	6.85	4.817	15.706
1987	current	1.530	8.34	9.687	19.557	3.565	6.27	5.213	15.048
1988	dollars)	1.422	19.60	12.803	33.834	3.490	5.90	5.712	15.102
Total		8.322	53.32	45.775	107.417	19.174	32.54	22.865	74.579

Table 8

Comparison of Data For Houses Known to Have Smoke Alarms
Rate Per Fire

Province	Smoke Alarms Sounded			Smoke Alarms did Not Sound			Ratio-Sounded/Not Sounded		
	Deaths	Injuries	Loss	Deaths	Injuries	Loss/house	Deaths	Injuries	Loss
Alta.	0.00216	0.1003	8,977	0.00323	0.1132	$15,500*	0.669	0.886	0.579
B.C.	0.00986	0.1056	28,590	0.01483	0.0793	$20,980	0.665	1.332	1.363
Ont	0.00651	0.1539	12,953	0.01189	0.1036	$ 6,633	0.548	1.486	1.953
Weighted Averages*	0.00680	0.1318	16,980	0.01091	0.0994	11,961	0.623	1.326	1.420

* Not converted to 1989 dollars – based on year of record

Table 9

Housing Population Estimates
One and Two Family Houses

Year	Ontario	Alberta	B.C.	Total
1984	2,073,000	573,000	715,000	3,361,000
1985	2,111,000	579,000	724,000	3,414,000
1986	2,164,000	586,000	735,000	3,485,000
1987	2,231,000	594,000	748,000	3,573,000
1988	2,301,000	602,000	763,000	3,666,000
Totals	10,880,000	2,934,000	3,685,000	17,499,000
With Alarms (77%)	8,378,000	2,259,000	2,837,000	13,474,000
Without Alarms (23%)	2,502,000	675,000	848,000	4,025,000

Estimated smoke alarm use, averaged over 1984–88 = 77%.

Estimated population with alarms = 13.47 million houses.

Estimated population without alarms = 4.02 million houses.

Table 10

Summary of Annual Risks in One and Two Family Houses With or Without Smoke Alarms (Assuming 75% Reliability)

1	Fatalities/million houses (including fire fighters)	– without smoke alarms	131.7
		– with smoke alarms	72.4
		Benefit	59.3
2	Injuries/million houses (including fire fighters)	– without smoke alarms	$9.12
		– with smoke alarms	$8.21
		Benefit	$0.91
3	Property loss/house	– without smoke alarms	$172.80
		– with smoke alarms	$128.30
		Benefit	$ 44.50
4	Indirect costs/house	– without smoke alarms	$11.23
		– with smoke alarms	$ 8.34
		Benefit	$ 2.89
5	Fire Services costs/house	– without smoke alarms	$72.00
		– with smoke alarms	$72.00
		Benefit	$ 0.00
		Total Savings per year	$48.30

Table 11

Summary of Annual Risks in One and Two Family Houses With or Without Smoke Alarms (Assuming 97% Reliability)

1	Fatalities/million houses (including fire fighters)	- without smoke alarms	131.7
		- with smoke alarms	55.7
		Benefit	76.0
2	Injuries/million houses (including fire fighters)	- without fire alarms	$9.12
		- with fire alarms	$7.93
		Benefit	$1.19
3	Property loss/house	- without fire alarms	$172.80
		- with fire alarms	$115.25
		Benefit	$ 57.55
4	Indirect costs/house	- without smoke alarms	$11.23
		- with smoke alarms	$ 7.49
		Benefit	$ 3.74
5	Fire Service costs/house	- without fire alarms	$72.00
		- with fire alarms	$72.00
		Benefit	None
		Total Savings per year	$62.48

Table 12

B.C. Fires in One and Two Family Houses

	Newer Houses				All Houses		
Data Year	Year of const.	Total No. of houses	No. of fires	Fires/1000 houses	Total no. of houses	No. of fires	Fires/1000 houses
1983	78-82	91,300	317	3.47	706,000	2659	3.77
1984	79-83	88,200	210	2.38	715,000	2395	3.35
1985	80-84	80,600	230	2.85	724,000	2848	3.93
1986	81-85	71,100	143	2.01	735,000	2511	3.42
1987	82-86	58,600	113	1.93	748,000	2355	3.15

Table 13

Alberta Fires in One and Two Family Houses

	Newer Houses				All Houses		
Data Year	Year of const.	Total No. of houses	No. of fires	Fires/1000 houses	Total No. of houses	No. of fires	Fires/1000 houses
1983	78-82	99,800	255	2.56	567,000	1849	3.26
1984	79-83	92,100	235	2.55	573,000	1731	3.02
1985	80-84	75,900	190	2.50	579,000	1727	2.98
1986	81-85	62,100	120	1.93	586,000	1602	2.73
1987	82-86	48,500	80	1.65	594,000	1567	2.64

Table 14

B.C. Fires in One and Two Family Houses

Data Year	Newer Houses				All Houses		
	Year of const.	Total no. of houses	No. of fires	Fires/1000 houses	Total no. of houses	No. of fires	Fires/1000 houses
1983	79–83	80,900*	274	3.38	706,000	2659	3.77
1984	80–84	75,000*	176	2.35	715,000	2395	3.35
1985	81–85	65,800*	173	2.63	724,000	2848	3.93
1986	82–86	52,000*	117	2.25	735,000	2511	3.42
1987	83–87	57,300*	113	1.97	748,000	2355	3.15

* includes only half of the houses constructed during the last year

Table 15

Alberta Fires in One and Two Family Houses

Data Year	Newer Houses				All Houses		
	Year of const.	Total no. of houses	No of fires	Fires/1000 houses	Total no. of houses	No. of fires	Fires/1000 houses
1983	79–83	86,000*	202	2.35	567,000	1849	3.26
1984	80–84	71,700*	191	2.66	573,000	1731	3.02
1985	81–85	58,700*	109	1.86	579,000	1727	2.98
1986	82–86	44,500*	91	2.04	586,000	1602	2.73
1987	83–87	39,700*	70	1.76	594,000	1567	2.64

* includes only half of the houses constructed during the last year

Table 16

Fire Record For Newer One and Two Family Houses
Based on Cumulative Data For B.C. and Alberta

Data Base	Data Year	Cumulative no. of fires	Cumulative no. of houses	Fires/1000 houses
Based on	1987	193	107,100	1.80
	1986-87	456	240,300	1.90
Tables	1985-87	876	396,800	2.21
	1984-87	1320	577,400	2.29
3 and 4	1983-87	1893	768,200	2.46
Based on	1987	183	97,000	1.89
	1986-87	391	193,500	2.02
Tables	1985-87	673	318,000	2.11
	1984-87	1040	464,700	2.24
5 and 6	1983-87	1516	631,600	2.40

Table 17

Fire Rates For All One and Two Family Houses
Based on Cumulative Data for B.C. and Alberta

Data Year	No. of fires	No. of houses	Fires/1000 houses	Fire Ratio - Newer to Older	
				Tables 3 and 4	Tables 5 and 6
1987	3922	1,342,000	2.92	0.62	0.65
1986-87	8035	2,663,000	3.02	0.63	0.67
1985-87	12,610	3,966,000	3.18	0.69	0.66
1984-87	16,736	5,254,000	3.19	0.72	0.70
1983-87	21,244	6,527,000	3.25	0.76	0.74

Table 18

Cumulative Fire Losses For B.C. and Alberta

Data Base	Data Year	Cumulative No. of Fires (Table 7)	Cumulative Fire Losses* ("Ref. 2")	Loss/fire*
Based on	1987	193	$ 4.05M	$21,000
	1986-87	456	$12.32M	$27,000
Tables	1985-87	876	$26.54M	$30,300
	1984-87	1320	$38.02M	$28,800
3 and 4	1983-87	1893	$51.51M	$27,210
Based on	1987	183	$ 3.40M	$18,600
	1986-87	391	$ 7.81M	$20,000
Tables	1985-87	673	$15.89M	$23,600
	1984-87	1040	$25.85M	$24,900
5 and 6	1983-87	1516	$36.91M	$23,600

* 1989 dollars

Table 19

Fire Loss Summary For the General Housing Stock
(Based on Data From Tables 17 and 18 in Phase 2 Report and Tables 7 and 8 in Phase 3.

Data Year	Cumulative Fire Losses* (Reference 2)	Cumulative No. of Fires (Table 8)	Property Loss/Fire	Property Loss Ratio – Newer Houses to Older Houses	
				Based on Tables 3 & 4	Based on Tables 5 & 6
1987	$ 60.0M	3,922	$15,300	1.37	1.22
1986-87	$126.7M	8,035	$15,800	1.71	1.27
1985-87	$204.6M	12,610	$16,200	1.87	1.45
1984-87	$271.4M	16,736	$16,200	1.78	1.54
1983-87	$342.7M	21,244	$16,100	1.69	1.47

* 1989 dollars

Table 20

Summary of Benefits From Providing Smoke Alarms in New Houses

	Without Alarms	With Alarms	Net Benefit
Fire Fatality Rate (Civilian & Fire Fighters)	33.4/M Houses	14.2/M Houses	19.2/M Houses
Injury costs (Civilian & Fire Fighter)	$ 8.75/House	$ 7.61/House	$ 1.14/House
Property Loss	$67.07/House	$44.80/House	$22.27/House
Indirect Costs	$ 4.38/House	$ 2.91/House	$ 1.47/House
Fire Services	NA	NA	NA
Total	$80.20/House	$55.32/House	$24.28/House

Appendix A

Calculation of the Effect of Smoke Alarms on House Safety

Year	Total Housing Stock	Estimated % With Alarms	Houses With Alarms	Houses Without Alarms	No. of Reported Fires	No. of Reported Fatalities	No. of Reported Injuries	Total Fire Loss
1980	5.575M	22%	1.226M	4.349M	29,510	442	1275	$394M***
1987	6.188M	82%	5.074M	1.114M	20,443	277	1307	$277M

** Reference 4 *** 1989 dollars

Calculations

x = reported event per million houses with alarms.
y = reported event per million houses without alarms.

1. Effect on reported fires.

1980 - $1.226x + 4.349y = 29,510$
1987 - $5.074x + 1.114y = 20,443$
Solving for x and y - x = 2706 fires/million houses.
y = 6023 fires/million houses.

(continued on next page)

2. Effect on fatalities.

1980 - $1.226x + 4.349y = 413$
1987 - $5.074x + 1.114y = 277$
Solving for x and y - $x = 34.4$ fatalities/million houses.
$y = 91.9$ fatalities/million houses.

3. Effect on injuries:

1980 - $1.226x + 4.349y = 1275$
1987 - $5.074x + 1.114y = 1307$
Solving for x and y - $x = 206$ injuries/million houses.
$y = 235$ injuries/million houses.

4. Effect on fire loss:

1980 - $1.226x + 4.349y = \$394$
1987 - $5.074x + 1.114y = \$277$
Solving for x and y - $x = \$37.00$/house.
$y = \$80.20$/house.

Summary of National Statistics Used in Calculations

Year	Total stock of one and two family houses	Deaths	Injuries	Total property losses (Millions of dollars)		No. of fires
	*	**	**	Unadjusted	1989 dollars	**
1980	5,575,000	442	1275	$233	$394	29,510
1981	5,568,000	413	1376	$232	$348	26,914
1982	5,706,000	394	1345	$266	$360	25,316
1983	5,786,000	336	1376	$247	$316	24,449
1984	5,867,000	333	1320	$244	$299	22,815
1985	5,946,000	304	1187	$264	$311	22,365
1986	6,055,000	283	1327	$247	$280	21,415
1987	6,188,000	277	1307	$255	$277	20,443

* Based on data provided by CMHC

** Based on the annual reports of "Fire Losses in Canada", prepared under the auspices of the Fire Commissioner of Canada

*** Assumed Index Values:

1980 - 59.2	1984 - 81.5	1988 - 96.1
1981 - 66.6	1985 - 84.8	1989 - 100
1982 - 73.8	1986 - 88.3	
1983 - 78.1	1987 - 92.1	